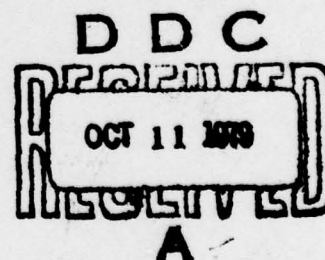
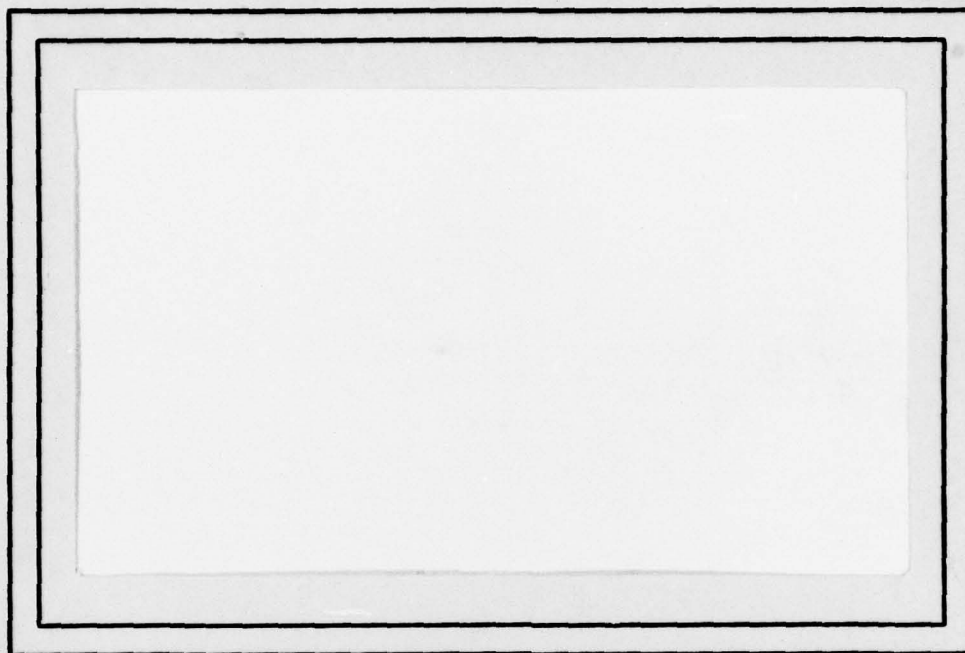


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 DAAG-53-76C-0138  
 DARPA Order-3206  
 11 October 1978

15) 6) POINT PATTERN MATCHING  
 BY RELAXATION

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 Azriel Rosenfeld  
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12) 43

# ABSTRACT

Let  $P=P_1, \dots, P_m$  and  $Q=Q_1, \dots, Q_n$  be two patterns of points. Each pairing  $(P_i, Q_j)$  of a point of  $P$  with a point of  $Q$  defines a relative displacement  $\delta_{ij}$  of the two patterns. We can define a figure of merit for  $\delta_{ij}$  according to how closely other point pairs coincide under  $\delta_{ij}$ . If there exists a displacement  $\delta_0$  for which  $P$  and  $Q$  match reasonably well, the pairings for which  $\delta_{ij} \approx \delta_0$  will have high merit scores, while other pairings will not. The scores can then be recomputed, giving weights to the other point pairs based on their own scores; and this process can be iterated. When this is done, the scores of pairs that correspond under  $\delta_0$  remain relatively high, while those of other pairs become low. Examples of this method of point pattern matching are given, and its possible advantages relative to other methods are discussed.

The support of the Defense Advanced Research Projects Agency and U.S. Army Night Vision Laboratory under Contract DAAG-53-76C-0138 (DARPA order 3206) is gratefully acknowledged, as is the help of Kathryn Riley in preparing this paper.

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## 1. Introduction

In [1] some experiments in point pattern matching are described. Given two point patterns  $P = P_1, \dots, P_m$  and  $Q = Q_1, \dots, Q_n$ , we count, for each displacement  $\underline{\delta}$  of  $P$  relative to  $Q$ , how many pairs  $(P_i, Q_j)$  lie closer together than some threshold  $t$ . If  $P$  and  $Q$  have many points in common, this process will yield a large match peak for that  $\underline{\delta}$  that maps these points into themselves, while others  $\underline{\delta}$ 's will yield at best low match values where a few pairs happen to coincide.

The matching process just described is essentially equivalent to cross-correlating  $P$  with a "blurred" version of  $Q$  in which each point has been expanded into a disk of radius  $t$ . (Actually, for computational simplicity, only displacements that map some  $P_i \in P$  into some  $Q_j \in Q$  were considered.) It will tolerate local distortions, as long as they do not generally give rise to relative displacements that exceed  $t$ . On the other hand,  $t$  must be substantially smaller than the average interpoint distance in  $P$  and  $Q$ , since otherwise many false matches will be detected.

This paper discusses an alternative approach to point pattern matching in which a figure of merit is assigned to each pair  $(P_i, Q_j)$ , according to how closely other pairs  $(P_h, Q_k)$  match when  $P_i$  is mapped into  $Q_j$ . Let  $\underline{\delta}_{ij}$  be the displacement that maps  $P_i$  into  $Q_j$ ; if there exists a displacement  $\underline{\delta}_0$  for which  $P$  and  $Q$  match reasonably well, and

$\delta_{ij}$  is close to  $\delta_0$ , then  $(P_i, Q_j)$  will have a high merit score, but otherwise it will not. The scores can then be recomputed, giving weights to the other point pairs  $(P_h, Q_k)$  based on their own scores; and this process can be iterated. When this is done, the scores of pairs that correspond under  $\delta_0$  remain relatively high, while those of other pairs become low.

The merit score computation is described in greater detail in Section 2, and some examples of point pattern matching by this method are given in Section 3. For earlier work on the use of iterative ("relaxation") methods in image matching see [2].



## 2. Match merit computation

When we pair  $P_i$  with  $Q_j$ , we would like to find  $Q$ 's in the same positions relative to  $Q_j$  that the  $P$ 's have relative to  $P_i$ . Let  $P_h$  and  $Q_k$  be any  $P$  and  $Q$  other than  $P_i$  and  $P_j$ , and let  $\delta_{ij}(h,k)$  be the position difference of  $P_h$  and  $Q_k$  when  $P_i$  is mapped into  $Q_j$ . If  $|\delta_{ij}(h,k)|$  is zero,  $Q_k$  is exactly in the same position relative to  $Q_j$  that  $P_h$  is relative to  $P_i$ , so that the pair  $(P_h, Q_k)$  should give the pair  $(P_i, Q_j)$  maximal support; while as  $|\delta_{ij}(h,k)|$  increases, this support should decline. Let the support given to  $(P_i, Q_j)$  by  $(P_h, Q_k)$  be denoted by  $\varphi(|\delta_{ij}(h,k)|)$ . In the experiments described in the next section, we used  $\varphi(x) = \frac{1}{1+x^2}$ ; many other functions could have been used instead.

For each  $P_h$ , there may be several  $Q_k$ 's that lie close to it; but we only want one  $Q_k$  to correspond to  $P_h$  when  $P_i$  is paired with  $Q_j$ . Thus it is reasonable to define the support to  $(P_i, Q_j)$  associated with  $P_h$  as

$$\max_{k \neq j} [\varphi(|\delta_{ij}(h,k)|)] \quad (1)$$

In this way, we can compute the support provided to  $(P_i, Q_j)$  by each  $P_h$ . To obtain the total support for  $(P_i, Q_j)$ , we average the contributions of all the  $P_h$ 's:

$$\frac{1}{m-1} \sum_{h \neq i} \{ \max_{k \neq j} [\varphi(|\delta_{ij}(h,k)|)] \} \quad (2)$$

We shall denote this quantity by  $s^{(0)}(P_i, Q_j)$ .

In computing  $s^{(0)}$ , we treated all pairs  $(P_h, Q_k)$  equally, since a priori any two points can correspond. Now, however, we can recompute the support, taking into account the fact that each pair has a figure of merit  $s^{(0)}(P_h, Q_k)$ . Specifically, the support given to  $(P_i, Q_j)$  by  $(P_h, Q_k)$  should depend not only on the position difference between  $P_h$  and  $Q_k$ , but also on their  $s^{(0)}$  value. These two factors can be combined in various ways; we have chosen to use their minimum, i.e., to define the support for  $(P_i, Q_j)$  given by  $(P_h, Q_k)$  as

$$\min[\varphi(|\delta_{ij}(h,k)|), s^{(0)}(P_h, Q_k)] \quad (3)$$

We can then compute the support for  $(P_i, Q_j)$  associated with  $P_h$  as

$$\max_{k \neq j} (\min[\varphi(|\delta_{ij}(h,k)|), s^{(0)}(P_h, Q_k)]) \quad (1')$$

and the total support for  $(P_i, Q_j)$  from all the  $P_h$ 's as

$$s^{(1)}(P_i, Q_j) = \frac{1}{m-1} \sum_{h \neq i} \{ \max_{k \neq j} (\min[\varphi(|\delta_{ij}(h,k)|), s^{(0)}(P_h, Q_k)]) \} \quad (2')$$

This process can then be iterated; at the  $r$ th step we have

$$s^{(r)}(P_i, Q_j) = \frac{1}{m-1} \sum_{h \neq i} \{ \max_{k \neq j} (\min[\varphi(|\delta_{ij}(h,k)|), s^{(r-1)}(P_h, Q_k)]) \} \quad (2*)$$

for  $r=1, 2, 3, \dots$

### 3. Experiments

The process described in Section 2 was applied to the same data sets used in [1]. In each of the following figures, parts (a-b) show the two point patterns  $P$  and  $Q$ . Part (c) tabulates, for each  $P_i \in P$ , the two points  $Q_j \in Q$  for which the match merit of the pair  $(P_i, Q_j)$  is highest. Part (d) shows the total match merit associated with each relative displacement of  $P$  and  $Q$ , multiplied by 100.

The point patterns in Figures 1 and 2 represent two sets of local features extracted from a picture of a tank and from a road map of the Washington, D.C. area, respectively. In each case, there is a strong match peak corresponding to the proper relative displacement of the two patterns. Note that the merit of the second best  $Q_j$  is not always very much lower than that of the best  $Q_j$ , but it is often at least twice as low.

Figures 3-5 show results for sets of edge points extracted from a succession of FLIR images of a tank. The comparisons are for frames 1 and 10, 1 and 5, and 5 and 10, respectively. The smearing of the peaks indicates the motion of the tank from frame to frame. Figures 6-7 show results using two different edge detectors on an image of a tank and of an APC.

Figures 8-11 show the results of applying various amounts of "random walk noise" to the second set of map feature points

used in Figure 2. The random jumps had uniformly distributed directions; their magnitudes were normally distributed with mean 0 and standard deviation 3%,  $4\frac{1}{2}\%$ , 6%, and 9% (of the picture diameter) in Figures 8-11, respectively. Good match peaks are obtained for the first three cases.

Figures 12-13 show the results of rotating one of the map feature point sets by  $5^\circ$  and  $10^\circ$  relative to the other. Good match peaks are obtained in both cases; in [1], on the other hand, the  $10^\circ$  rotation did not yield a good peak.

In all of these examples, the results shown are for the fourth iteration (i.e.,  $s^{(4)}(P_i, Q_j)$ ). Figure 14 shows the results of iterations 0,1,2,3 for the case in Figure 1. Note that even for  $s^{(0)}$ , the peak is four times higher than the largest non-peak values, and that this ratio is (at least) maintained while the number of non-peak values drops substantially. Note also that in this case the  $s^{(3)}$  values are the same as the  $s^{(4)}$  values in Figure 1d--i.e., the process has stabilized after three iterations.



#### 4. Discussion

The relaxation scheme for point pattern matching described in this paper is comparable in computational cost to the simpler scheme of [1]. Both schemes consider only the  $mn$  displacements that pair off all possible points of  $P$  with points of  $Q$ ; and for each such displacement, they compare all other points of  $P$  with all other points of  $Q$ . Thus the total amount of computation is  $O(m^2n^2)$ . The individual computations involved in the relaxation scheme are somewhat more complex, and must be iterated several times; but this additional complexity represents only a constant factor which does not grow with  $m$  and  $n$ .

On the other hand, the relaxation approach appears to be more tolerant to global distortion than the method of [1]. For example, consider the case where one pattern is rotated relative to the other. This rotation shifts different parts of the pattern in different directions; hence when we compute a match score for any given relative shift, as in [1], it will be relatively low. On the other hand, for any given point  $P$ , there will be neighboring points that are shifted in approximately the same way as  $P$ , so that in the relaxation scheme these points will provide some support for pairing  $P$  with an appropriate  $Q$ . Thus the relaxation method should give better results under rotation than the method of [1], and this is

indeed the case (cf. Figures 12-13).

In summary, the relaxation approach deserves consideration as a method of evaluating point pattern matches under distortion.

### References

1. D.J. Kahl, A. Rosenfeld, and A. Banker, Some experiments in point pattern matching, Univ. of Md. Computer Science Ctr. TR-690, September 1978.
2. L.S. Davis and A. Rosenfeld, An application of relaxation labelling to spring-loaded template matching, Proc. 3IJCPR, November 1976, 591-597.

c)

ipoint	match	confidence	next best
A 10 23	10 28	0.12	18 31
B 12 27	13 26	0.10	10 28
C 21 27	19 23	0.05	18 31
D 23 27	25 25	0.08	20 20
E 9 26	10 28	0.09	18 31
F 26 25	25 25	0.10	20 20
G 9 24	7 23	0.11	10 28
H 8 23	7 23	0.10	10 28
I 10 23	7 23	0.08	10 28
J 27 21	27 19	0.1	25 25
K 6 20	7 23	0.07	13 26
L 23 19	22 21	0.1	20 20
M 14 17	14 15	0.09	16 18
N 5 16	5 16	0.10	7 23
O 15 16	14 15	0.10	16 18
P 18 16	18 15	0.1	16 18
Q 16 15	18 15	0.09	14 15
R 18 15	18 15	0.09	16 18
S 7 9	7 9	0.09	10 14
T 17 9	17 9	0.09	18 15

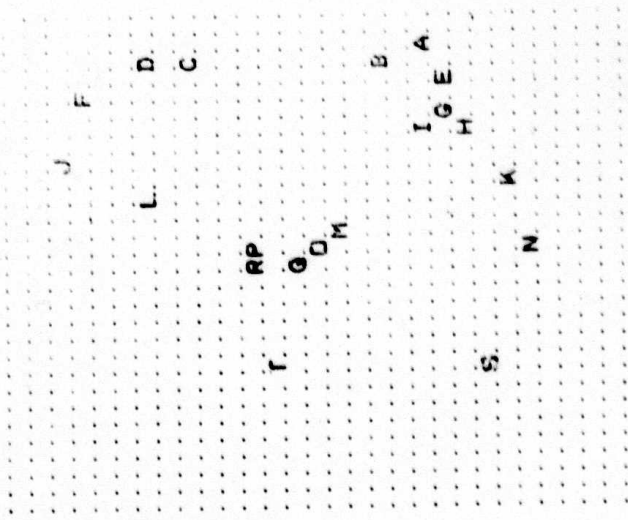
Figure 2 (a-c)



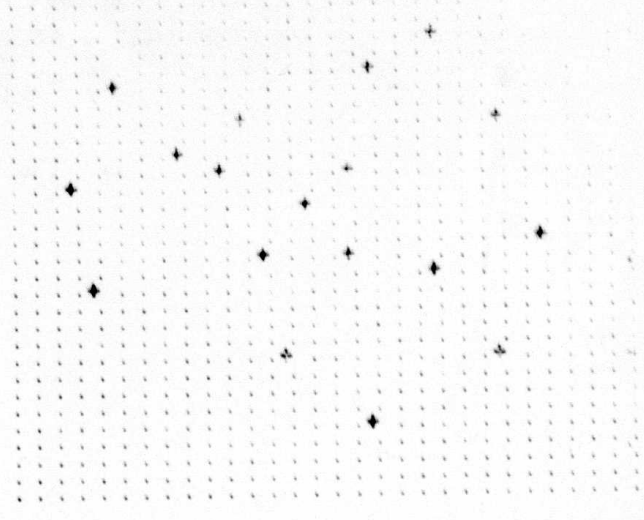
[illegible]

Figure 1d

a)



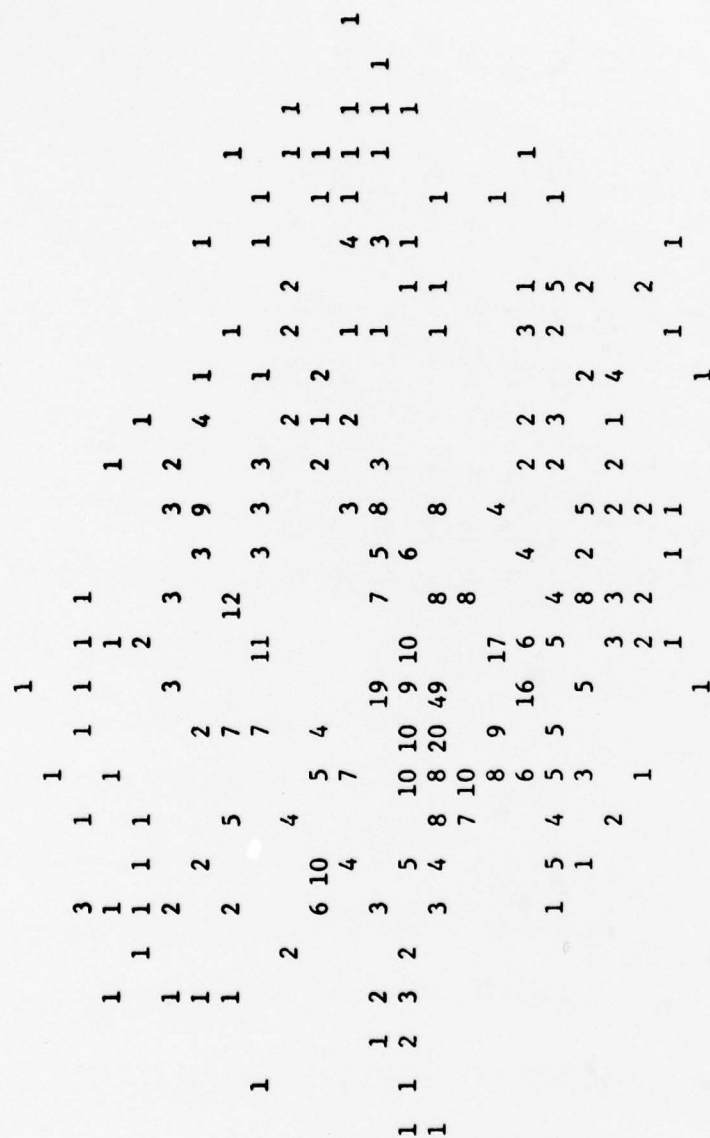
b)



c)

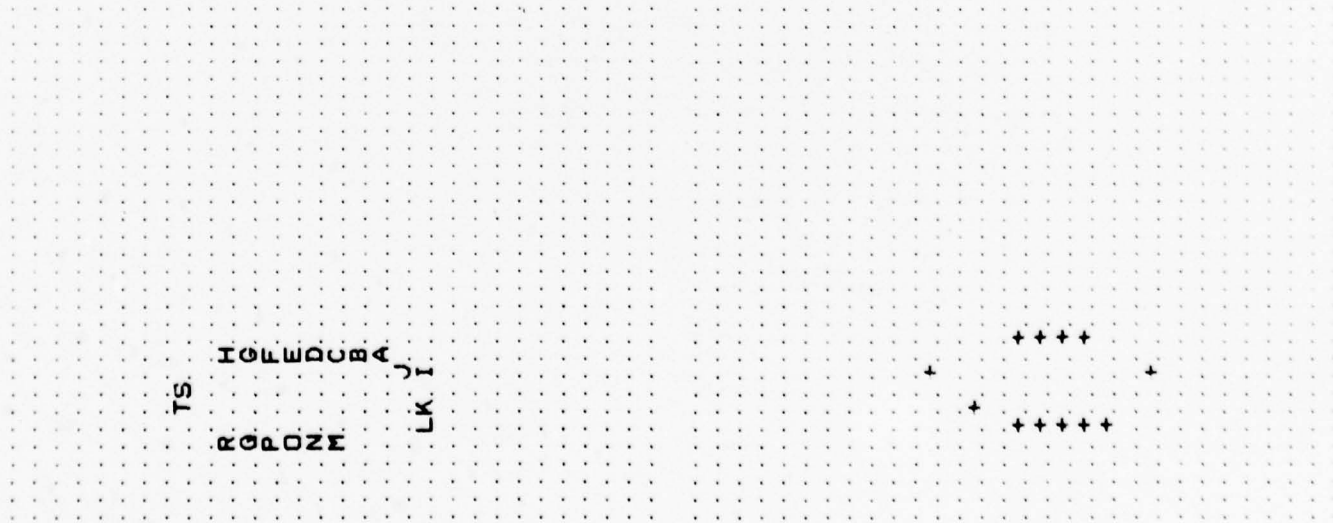
ipoint	match	confidence	next best
A 10 28	10 28	0.12	18 31
B 12 27	13 26	0.10	10 28
C 21 27	19 23	0.05	18 31
D 23 27	25 25	0.08	20 20
E 9 26	10 28	0.09	18 31
F 26 25	25 25	0.10	20 20
G 9 24	7 23	0.11	10 28
H 8 23	7 23	0.10	10 28
I 10 23	7 23	0.08	10 28
J 27 21	27 19	0.1	25 25
K 6 20	7 23	0.07	13 26
L 23 19	22 21	0.1	20 20
M 14 17	14 15	0.09	16 18
N 5 16	5 16	0.10	7 23
O 15 16	14 15	0.10	16 18
P 18 16	18 15	0.1	16 18
Q 16 15	18 15	0.09	14 15
R 18 15	18 15	0.09	16 18
S 7 9	7 9	0.09	10 14
T 17 9	17 9	0.09	18 15

Figure 2 (a-c)



**Figure 2d**

a)



b)

c)

ipoint	match	confidence	next best
A 13 10	12 11	0.26	
B 14 10	12 11	0.29	
C 15 10	12 11	0.29	
D 16 10	13 11	0.29	12 11 0.27
E 17 10	14 11	0.29	13 11 0.27
F 18 10	15 11	0.29	14 11 0.27
G 19 10	15 11	0.26	14 11 0.22
H 20 10	15 11	0.22	14 11 0.17
I 11 9	9 9	0.25	12 11 0.13
J 12 9	9 9	0.26	12 11 0.18
K 11 7	9 9	0.26	12 11 0.07
L 11 6	9 9	0.19	12 11 0.04
M 15 5	12 6	0.27	11 6 0.26
N 16 5	13 6	0.27	12 6 0.26
O 17 5	14 6	0.27	13 6 0.25
P 18 5	15 6	0.27	14 6 0.25
Q 19 5	17 7	0.25	19 9 0.09
R 20 5	17 7	0.25	19 9 0.10
S 22 8	19 9	0.26	15 11 0.08
T 22 7	19 9	0.25	15 11 0.05

Figure 3 (a-c)



[illegible]

**Figure 3d**

a)

TS  
R  
H  
G  
P  
O  
N  
M  
E  
D  
C  
B  
A  
J  
I  
K  
L  
M  
N  
O  
P  
Q  
R  
S  
T

b)

+

c)

ipoint	match	confidence	next best
A 13 10	16 10	0.39	15 10 0.38
B 14 10	17 10	0.39	16 10 0.38
C 15 10	18 10	0.38	17 10 0.37
D 16 10	19 10	0.38	18 10 0.37
E 17 10	20 10	0.38	19 10 0.37
F 18 10	21 10	0.37	20 10 0.36
G 19 10	22 10	0.37	21 10 0.36
H 20 10	22 10	0.36	21 10 0.33
I 11 9	15 10	0.33	
J 12 9	15 10	0.36	
K 11 7	14 7	0.36	15 10 0.14
L 11 6	14 7	0.36	15 10 0.08
M 15 5	18 5	0.35	14 7 0.13
N 16 5	19 5	0.35	18 5 0.35
O 17 5	20 5	0.35	19 5 0.34
P 18 5	21 5	0.35	20 5 0.34
Q 19 5	22 5	0.34	21 5 0.34
R 20 5	22 5	0.34	21 5 0.31
S 22 8	22 8	0.27	24 10 0.21
T 22 7	22 7	0.26	22 8 0.25

Figure 4 (a-c)



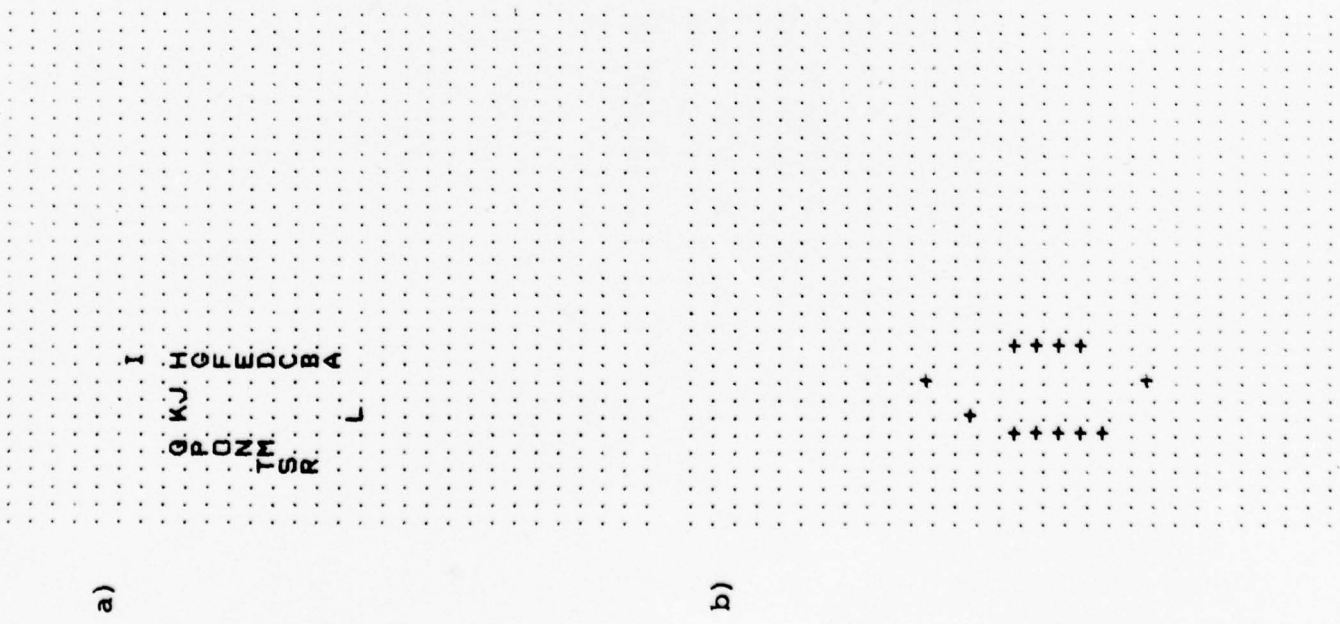


Figure 5 (a-c)



1	4	8	13	14	19	15	17	11	8	4	1	
					5	5	5	4	3	3	2	1
	4	6	8	0	0							
2	4	12	18	23	28	31	17	33	28	23	16	11
									6	2	1	
												1
3	5	15	45	87	136	207	207	187	162	147	61	30
												10
						21	45	120	96	110	55	29
						7	10	14	16			
										11	8	5
1	2	3	10	12	7	9			11	20	16	12
										8		
						2	3	3				
						2	5	7	9	8	6	5
										1	2	4
											6	5
												2

Figure 5d



1  
2 1

1  
1 2 3 3 3 4 3 1 1 1  
1 2 3 4 4 3 2

1 5 13 27 12 8  
8 19 66 61  
11 26 147 80  
13 22 88 347 91 22  
25 42 59 281 55  
11 17 25 112 49 17  
9 13 18 38 34 11  
7 17 21 10 9 6  
5 13 14 5  
4 5 4 4  
3 4 4 8  
2 6 8  
3 11 3  
6 15  
5 7 2  
5 2 4 1  
4 2 1 1  
1 2 1

Figure 6d

a)

ONM

R P  
G B

KJ  
LINGFEA

b)

+

c)

ipoint	match	confidence	next best
A 16 22	16 22	0 45	
B 19 21	19 18	0 27	21 21 0 24
C 20 21	21 21	0 40	16 21 0 07
D 21 21	21 21	0 45	16 22 0 05
E 16 21	16 21	0 44	16 22 0 40
F 16 20	16 20	0 44	16 21 0 40
G 16 19	16 19	0 44	16 20 0 40
H 16 18	16 18	0 43	16 19 0 39
I 16 17	16 17	0 43	16 18 0 39
J 17 17	16 17	0 41	16 18 0 34
K 17 16	16 16	0 40	16 17 0 34
L 16 16	16 16	0 43	16 17 0 39
M 25 17	25 16	0 41	26 17 0 38
N 25 16	25 16	0 42	26 17 0 33
O 25 15	25 15	0 42	25 16 0 38
P 20 14	20 13	0 41	19 13 0 38
Q 19 13	19 13	0 41	16 15 0 11
R 21 13	20 13	0 39	19 13 0 23

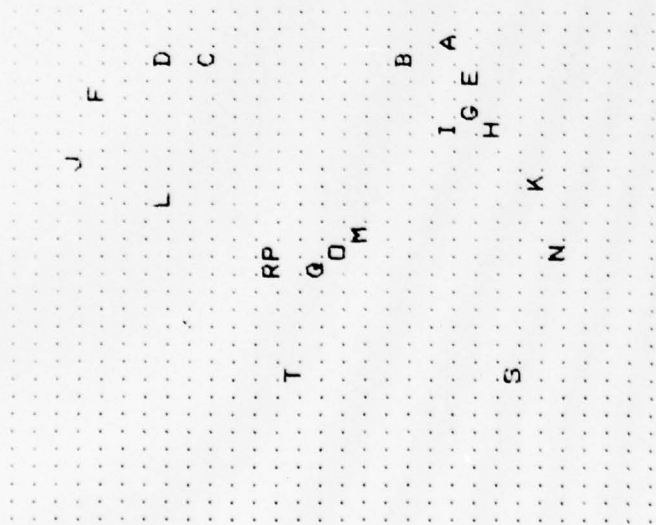
Figure 7 (a-c)



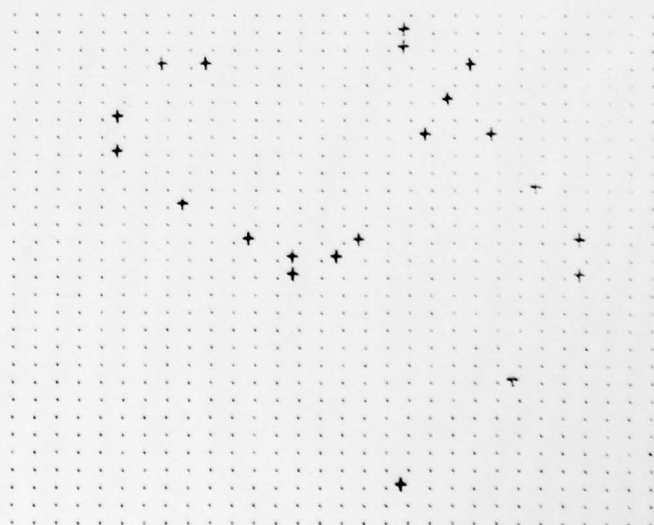
Figure 7d

ipoint	match	confidence	next best
A 10 28	9 27	0.25	12 28
B 12 27	12 28	0.25	12 29
C 21 27	21 27	0.26	12 28
D 23 27	23 27	0.26	21 27
E 9 26	9 27	0.25	12 28
F 26 25	25 24	0.24	23 27
G 9 24	8 23	0.24	10 25
H 8 23	8 23	0.25	10 25
I 10 23	8 23	0.22	10 25
J 27 21	25 22	0.20	25 24
K 6 20	6 20	0.25	8 23
L 23 19	22 19	0.24	25 22
M 14 17	14 17	0.24	11 23
N 5 16	4 17	0.23	4 15
O 15 16	15 16	0.24	14 17
P 18 16	17 16	0.24	19 17
Q 16 15	15 16	0.23	14 17
R 18 15	17 15	0.23	17 16
S 7 9	7 9	0.23	4 15
T 17 9	17 15	0.02	17 16

c)



a)



b)

Figure 8 (a-c)

[illegible]

Figure 8d

ipoint	match	confidence	next best
A 10 28	11 26	0.16	13 29 0.12
B 12 27	11 26	0.19	13 29 0.15
C 21 27	22 27	0.18	22 27 0.18
D 23 27	22 27	0.19	22 27 0.19
E 9 26	9 24	0.17	11 26 0.16
F 26 25 22 27	26 25 0.06	0.19	22 27 0.06
G 9 24	9 24	0.18	11 26 0.13
H 8 23	8 22	0.18	9 24 0.17
I 10 23	9 24	0.16	11 26 0.11
J 27 21	26 19	0.16	26 25 0.04
K 6 20	5 22	0.14	8 22 0.12
L 23 19	23 19	0.18	26 19 0.12
M 14 17 22 27	13 16 0.00	0.17	22 27 0.00
N 5 16	6 17	0.16	8 22 0.02
O 15 16	15 16	0.17	13 16 0.16
P 18 16	18 16	0.17	15 16 0.12
Q 16 15	16 15	0.17	15 16 0.15
R 18 15	18 16	0.16	15 16 0.11
S 7 9	7 9	0.16	13 16 0.00
T 17 9	18 13	0.06	16 15 0.00

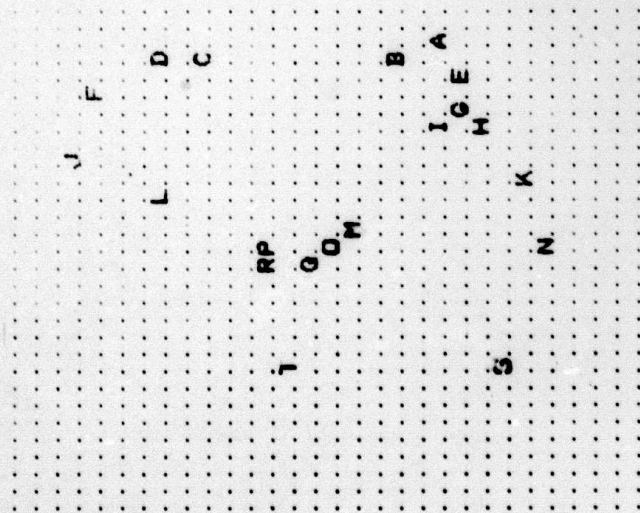
Figure 9 (a-c)

[illegible]

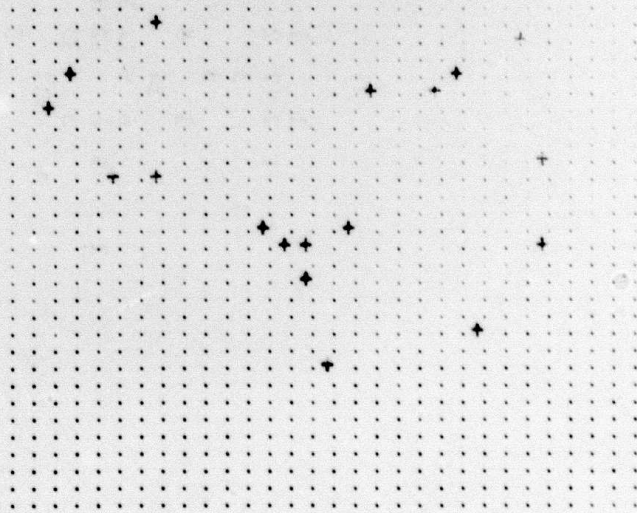
**Figure 9d**



a)



b)



c)

ipoint	match	confidence	next best
A 10 28	9 26	0 09	9 26 0 09
B 12 27	13 25	0 08	10 25 0 08
C 21 27	23 29	0 13	10 25 0 00
D 23 27	23 29	0 15	10 25 0 00
E 9 26	9 26	0 15	9 26 0 15
F 26 25	27 26	0 15	23 29 0 04
G 9 24	10 25	0 15	6 28 0 04
H 8 23	10 25	0 12	6 28 0 03
I 10 23	10 25	0 14	6 28 0 02
J 27 21	28 24	0 12	27 26 0 05
K 6 20	5 21	0 14	6 28 0 01
L 23 19	23 20	0 14	25 20 0 13
M 14 17	14 17	0 14	13 25 0 01
N 5 16	5 16	0 14	5 21 0 05
O 15 16	16 16	0 14	14 17 0 14
P 18 16	18 17	0 14	16 16 0 11
Q 16 15	16 16	0 14	14 17 0 11
R 18 15	17 16	0 13	18 17 0 12
S 7 9	8 11	0 12	5 16 0 02
T 17 9	15 9	0 11	16 14 0 04

Figure 10 (a-c).

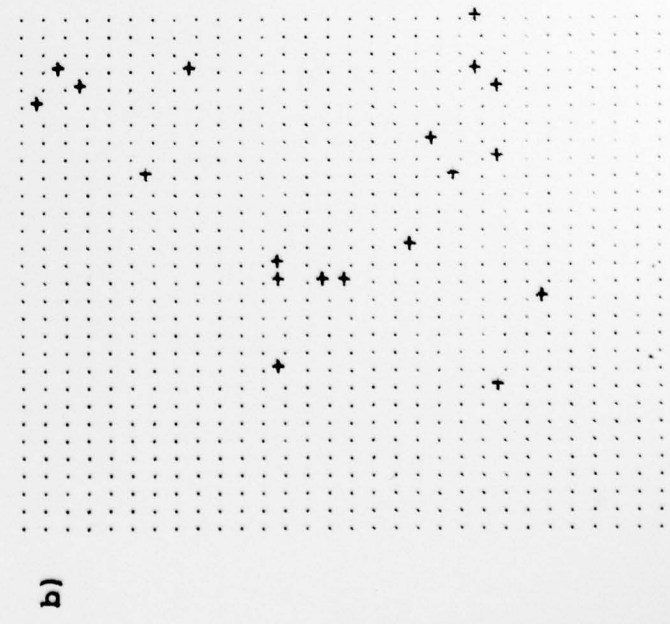
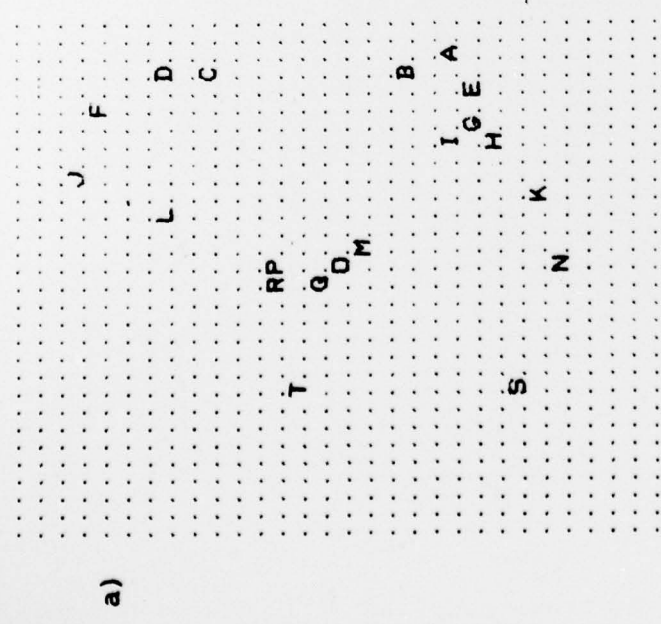
1	3	2	2	1	
1	1	1	1		
1		2	2		
	2	2	4		
1	3	4	6	4	3
	5	14	27	16	1
		22	18	11	13
	6	21	12	73	13
	6	11	41	42	13
	5	8	11	84	11
			36	47	9
	8				4
1	1	3	4	9	
					2
	1	1	1	1	
		1	1	1	
1					

Figure 10d

ipoint	match	confidence	next best
A 10 28	9 27	0.13	9 30
B 12 27	9 27	0.08	11 23
C 21 27	22 27	0.13	11 23
D 23 27	22 27	0.13	11 23
E 9 26	9 27	0.14	8 26
F 26 25	27 26	0.13	28 27
G 9 24	11 23	0.12	8 26
H 8 23	8 22	0.13	11 23
I 10 23	11 23	0.12	8 26
J 27 21	24 21	0.08	29 25
K 6 20	8 22	0.09	10 21
10 21	0.06		
L 23 19	24 21	0.10	22 27
M 14 17	15 15	0.11	12 17
N 5 16	6 14	0.11	8 22
O 15 16	15 15	0.12	12 17
P 18 16	18 16	0.12	15 15
Q 16 15	16 15	0.12	15 15
R 18 15	18 15	0.12	18 16
S 7 9	8 9	0.11	6 14
T 17 9	18 10	0.11	16 15

c)

Figure 11 (a-c)



[illegible]

**Figure 11d**

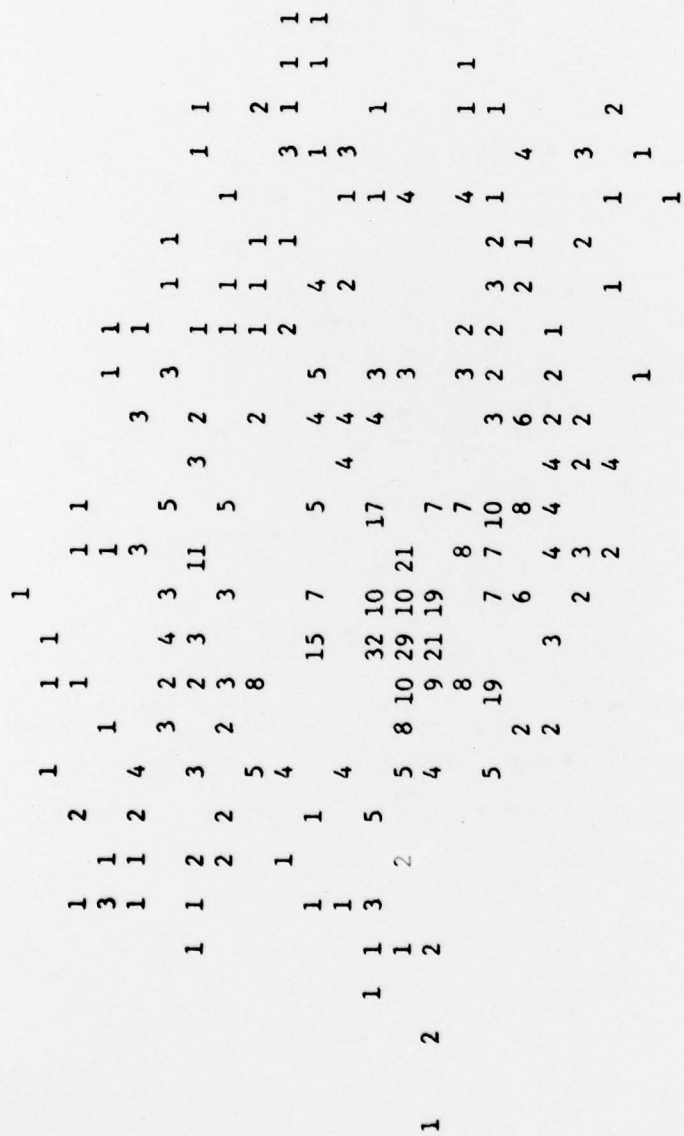


ipoint	match	confidence	next best
A 10 28	11 28	0.12	19 30
B 12 27	11 28	0.11	19 30
C 21 27	19 30	0.07	20 19
D 23 27	25 24	0.05	20 19
E 9 26	8 23	0.08	11 28
F 26 25	25 24	0.11	20 19
G 9 24	8 23	0.11	11 28
H 8 23	8 23	0.11	11 28
I 10 23	8 23	0.11	11 28
J 27 21	27 18	0.07	25 24
K 6 20	5 17	0.07	8 23
L 23 19	22 20	0.10	20 19
M 14 17	14 16	0.11	15 20
N 5 16	5 17	0.10	8 23
O 15 16	14 16	0.10	16 18
P 18 16	17 15	0.1	16 18
Q 16 15	17 15	0.1	14 16
R 18 15	17 15	0.1	16 18
S 7 9	7 10	0.09	10 15
T 17 9	16 9	0.09	17 15

c)

Figure 12 (a-c)





ipoint	match	confidence	next best
A 10 28	12 28	0.08	20 30 0.03
B 12 27	12 28	0.11	20 30 0.03
C 21 27	20 30	0.08	
D 23 27	20 30	0.05	
E 9 26	9 24	0.09	12 28 0.06
F 26 25	26 23	0.09	20 19 0.02
G 9 24	9 24	0.11	12 28 0.04
H 8 23	9 24	0.10	12 28 0.03
I 10 23	9 24	0.11	12 28 0.04
J 27 21	26 23	0.08	20 19 0.01
K 6 20	5 18	0.08	9 24 0.04
L 23 19	22 19	0.10	20 19 0.07
M 14 17	14 16	0.09	16 18 0.08
N 5 16	5 18	0.09	15 20 0.02
O 15 16	14 16	0.1	16 18 0.08
P 18 16	17 15	0.09	16 18 0.08
Q 16 15	17 15	0.09	14 16 0.08
R 18 15	17 15	0.09	16 18 0.06
S 7 9	6 11	0.08	10 16 0.02
T 17 9	16 9	0.09	17 15 0.02

c)

Figure 13 (a-e)

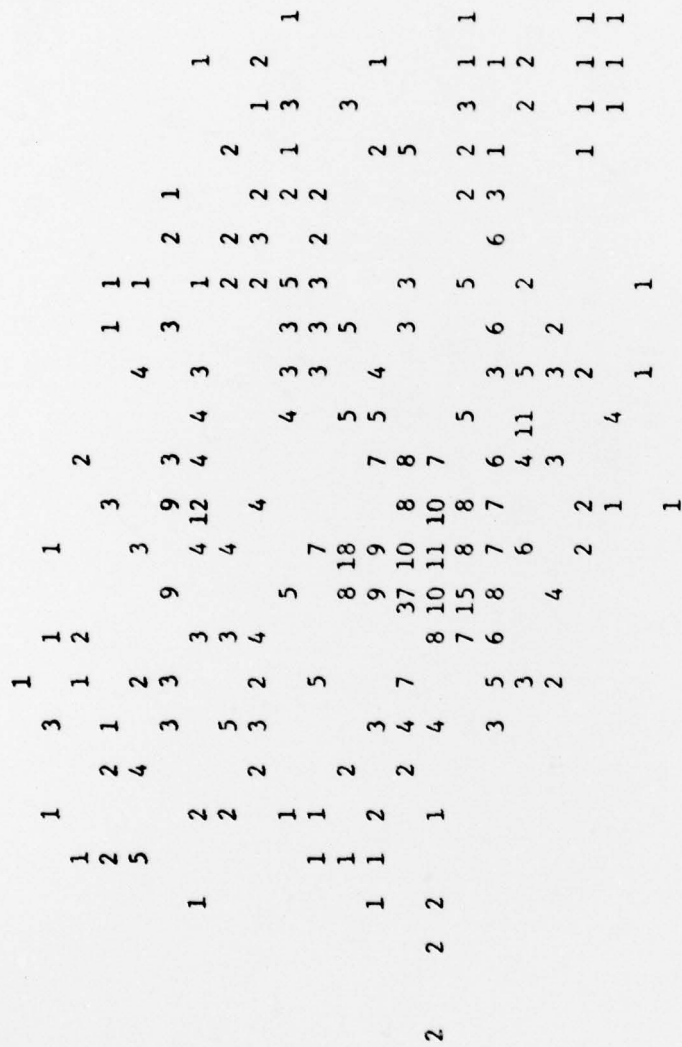


Figure 13d

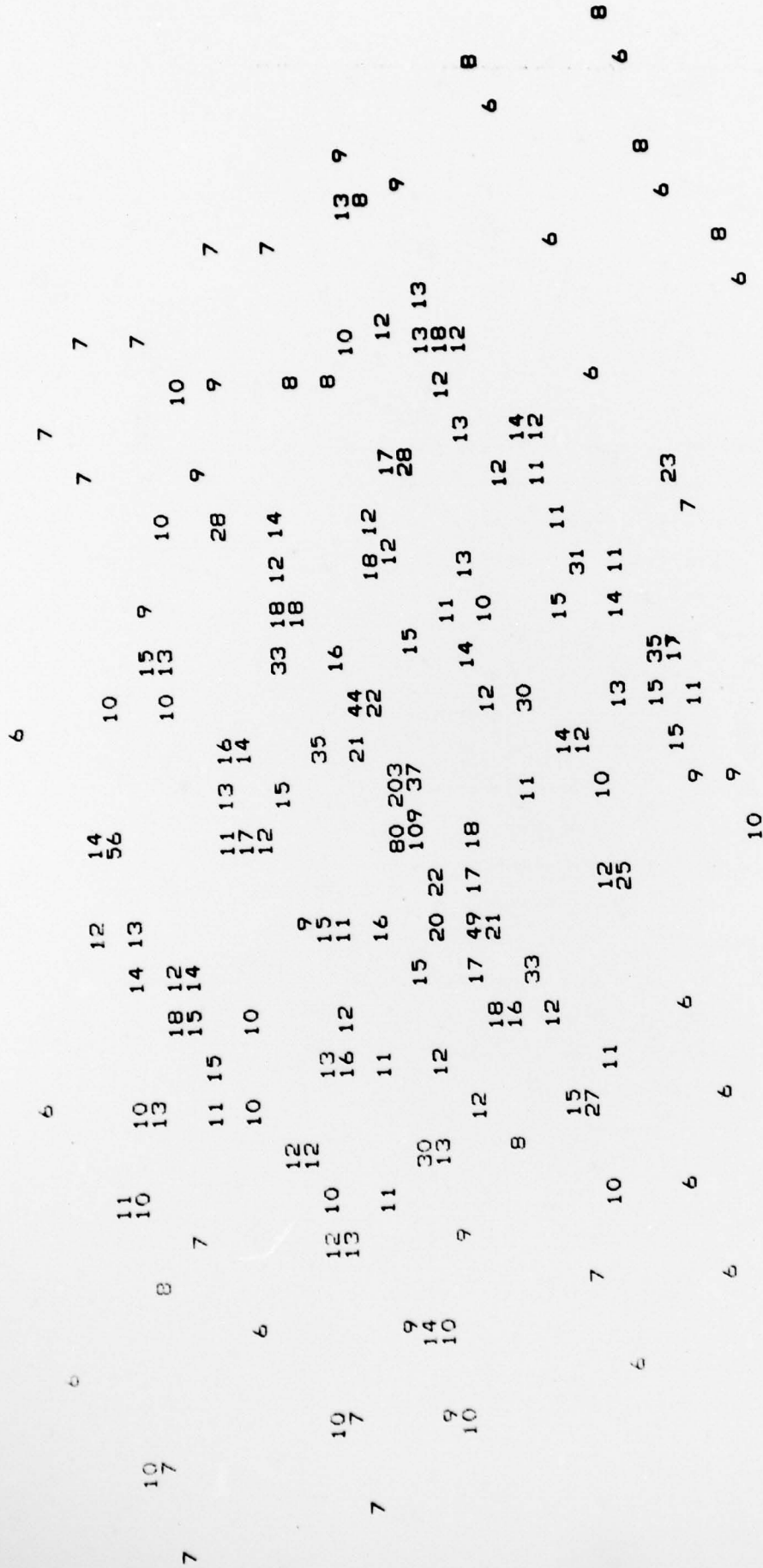


Figure 14a



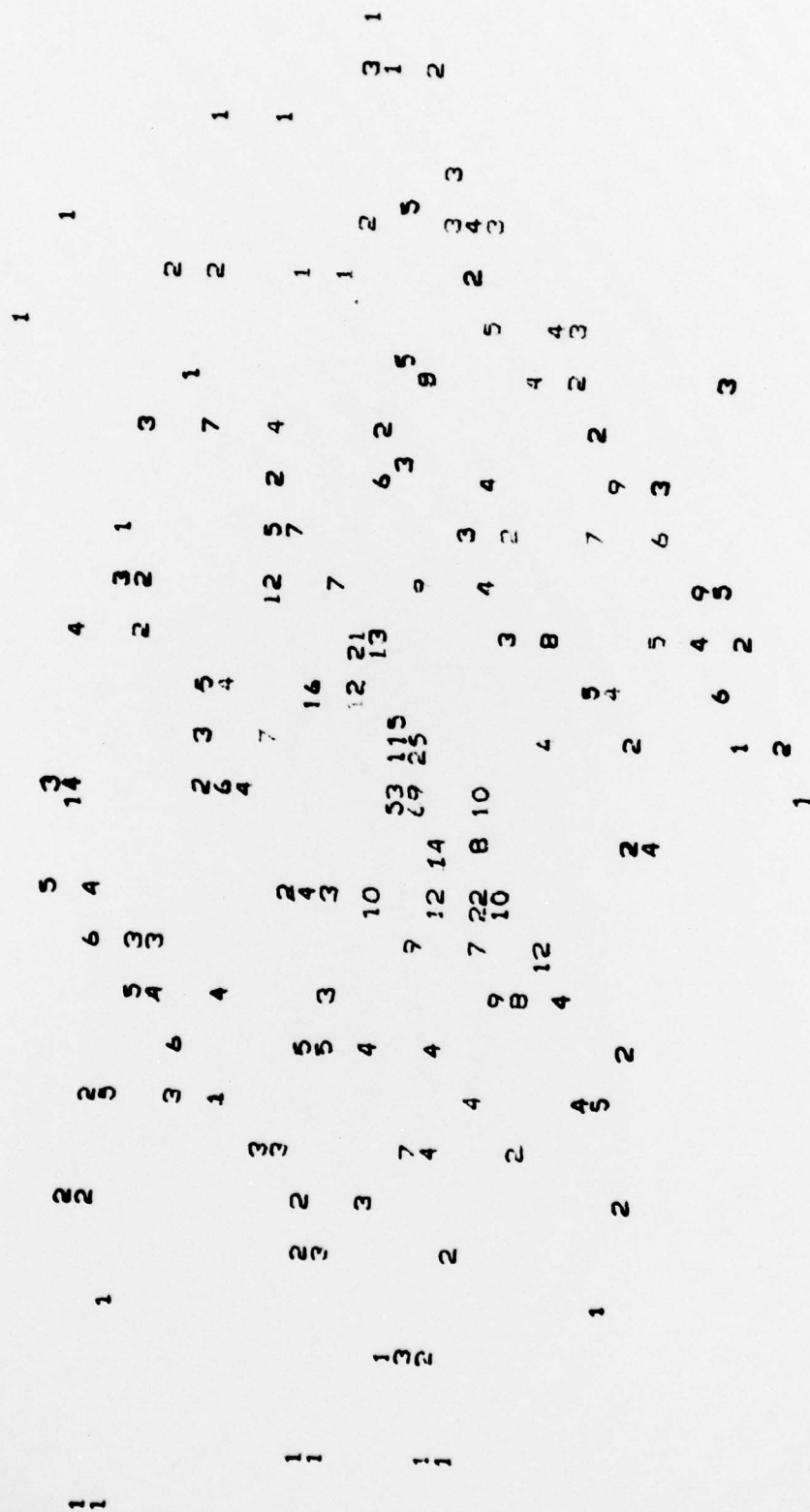
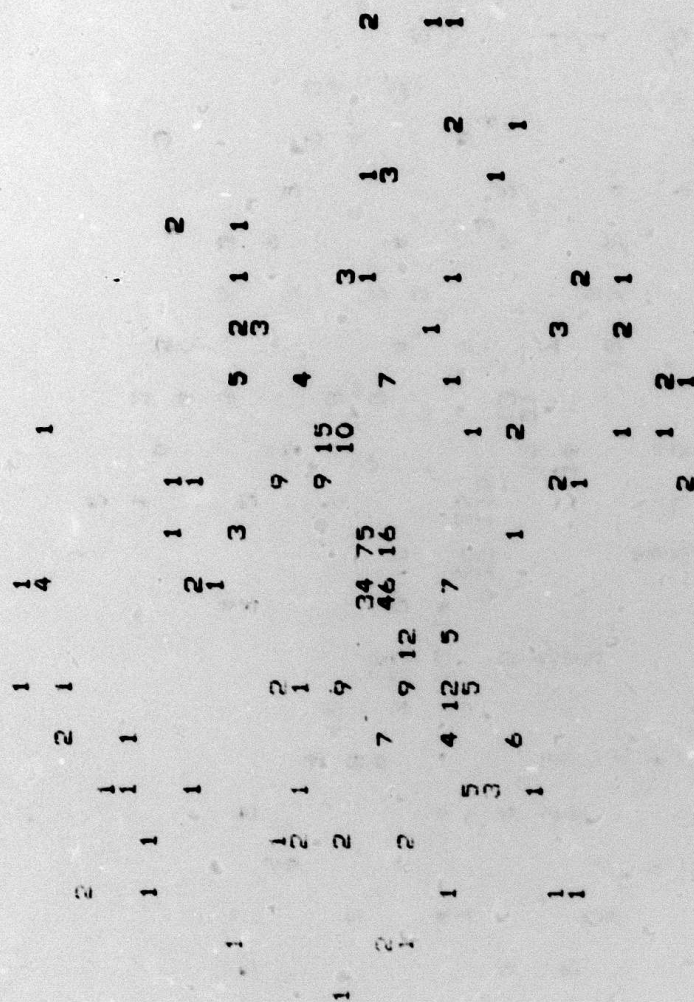


Figure 14b





**Figure 14c**



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based on their own scores; and this process can be iterated. When this is done, the scores of pairs that correspond under  $\delta_0$  remain relatively high, while those of other pairs become low. Examples of this method of point pattern matching are given, and its possible advantages relative to other methods are discussed.

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